Polyacrylamide Demonstration Project

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Abstract

In 1998, The Southeast Weld Soil Conservation District (SEWSCD) applied for a multi-media pesticide and water demonstration with the Environmental Protection Agency (EPA). The primary goal of this project was to demonstrate the reduction of non-point source pollution from agricultural activities through the use of polyacrylamide (PAM). Research has shown that PAM added to irrigation water binds the soil particles together into aggregates, preventing them from leaving the field[1]. Agricultural chemicals, which bind to soil particles, are also retained on the soil surface with the use of PAM[2]. Water and sediment samples were taken from three furrow-irrigated fields and analyzed for agricultural chemical content during the 1998 and 1999 growing seasons. Field corn, sugarbeets and dry beans were the crops grown for the project. Each field was divided into two, with one side irrigated with PAM treated water and the other with untreated water. Water and sediment samples were tested for NO_3-NO_2, NH_3, total Kjeldahl N, total P, and pesticides as they were applied. Once the quantities of chemicals carried off the field with runoff was known an economic analysis was performed detailing the costs associated with agricultural chemical applications versus the cost of using PAM. Use of PAM in irrigation water saved 6822.82 kg/ha in topsoil, 1.6 kg/ha nitrogen, 4.84 kg/ha phosphorus, and 0.36 kg/ha Lorsban 15G for total monetary savings of $156.03/ha. Applying PAM at the recommended rate of 10ppm with every other irrigation cost $36.96/ha. Net savings obtained by applying PAM with irrigation water were $119.07/ha. Additional savings would be realized over the long term in improved water quality, increased effectiveness of pesticides in controlling pests, maintenance of crop yields and other considerations.

Introduction

SEWSCD comprises 260,000 acres located in the South Platte River Basin in southern Weld County, Colorado. Approximately 35,000 acres are irrigated, and are mostly used to grow alfalfa, wheat, corn, sugarbeets, and dry beans. Furrow irrigated acres used to grow corn, sugarbeets and dry beans experience erosion as irrigation water is applied to clean tilled, loose soil. As the water passes through the soil profile or runs off the end of the field, it carries nutrients and pesticides with it, making them unavailable for crop use or reducing their effectiveness in controlling crop pests. Once soil sediments and agricultural chemicals leave the field they can contaminate ground and surface waters. SEWSCD has several lakes, reservoirs, and perennial streams within its boundaries that could be affected by these contaminants[3]. In addition, most area residents are dependent on domestic wells which can also be contaminated[3].

Agricultural chemicals can be classified as mobile or immobile. Mobile chemicals tend to be water-soluble and therefore move with the soil water. Immobile chemicals tend to bond to soil particles. Immobile chemicals remain in the soil unless the soil erodes as it does under furrow irrigation. When PAM is added to irrigation water, it binds soil particles together into aggregates, preventing them from eroding from the furrow[2]. Many immobile chemicals are retained in the soil with the use of PAM instead of being washed off the field with eroded sediments[3]. PAM has been shown to reduce irrigation induced erosion from furrow irrigated fields by as much as 94 percent[4] and a corresponding reduction in immobile agricultural chemicals in runoff might be observed.

There are some producers in the area who have begun using PAM as an inexpensive way of maintaining soil fertility and improving infiltration. Demonstrating that PAM reduces the loss of agricultural chemicals would encourage more producers to use it since the cost of application would be at least partially made up by a reduction in the amount of agricultural chemicals needed to produce a crop or by the increased effectiveness of the applied chemicals. Widespread reduction in non-point source pollution produced as these chemicals leave the field would be of great public benefit as water quality in agricultural areas may cease to decline, and perhaps even improve over time.

Materials and Methods

Five fields were selected as demonstration sites over the course of the two-year project. The corn field used in 1998 was used to grow dry beans in 1999. The three SEWSCD producers who farmed these fields were instructed to follow their normal farming practices with the exception of adding 0.6 ounces granulated anionic PAM per cubic foot of water (10ppm or one pound per acre) to one half of their fields[4] during the furrow advance phase. PAM was to be applied to the first irrigation of the season and any irrigation following field cultivation, not to exceed every other irrigation. All of the fields had approximately 0.5 percent slope, 2600 feet (808 meters) furrow length, and a loamy surface soil texture. These characteristics were chosen because such fields are typical in the Prospect Valley where furrow irrigation is most concentrated in the SEWSCD. Each field was divided in half; one half was irrigated with PAM treated water, the other half with untreated water. Samples of irrigation water were taken at sites where water entered a selected furrow on each side of each field, and where water exited the same furrows (FIGURE 1).

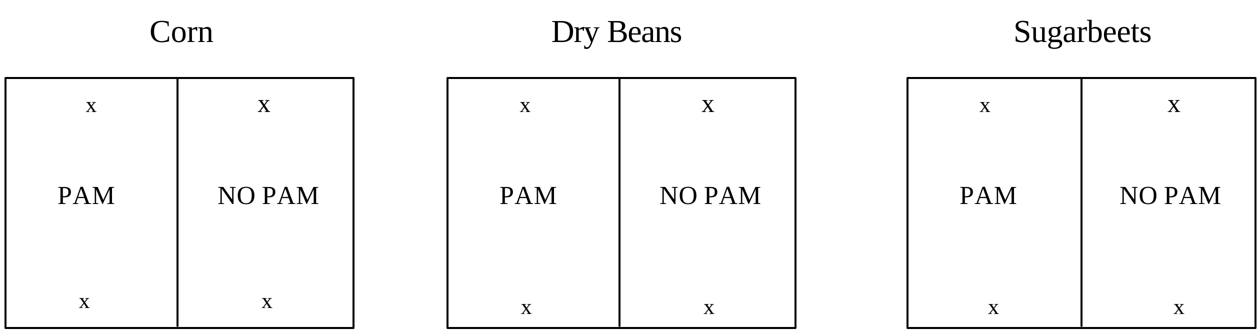

FIGURE 1

The same sampling technician was responsible for taking samples in both years and was trained to follow EPA protocols for waster sampling. Samples were taken according to the following schedule for a 12-hour irrigation set:

1 Time = 0 (when water begins to flow at a given site)
2 0 + 1 hour
3 0 + 2 hours
4 0 + 4 hours
5 0 + 5 hours

The flow rate was measured whenever a sample was taken. After all the samples for a given site were collected for that irrigation, they were composited in proportion to their flow rate to form a single sample that would accurately represent the irrigation event for that site. These samples were sent to the EPA Region VIII Laboratory for analysis. Each composited sample was tested for Total Suspended Solids (TSS), nitrate-nitrite (NO_3-NO_2), ammonia (NH_3), total Kjeldahl nitrogen, and total phosphorus. Samples that were obtained immediately following a pesticide application were also tested for that pesticide. The EPA performed all analytical procedures in accordance with its own methods.

Results and Discussion

Which data was included: The project ran into difficulties from a variety of sources. In 1998, The EPA was in the process of moving to its new facility in Golden, Colorado. The first irrigation samples from the sugarbeet field could not be analyzed by the EPA before the holding limits for the samples had been reached. As a result, the data from the first irrigation on the sugarbeet field in 1998 was lost entirely. The remainder of the sugarbeet data was included for analysis. In 1999, the field selected for sugarbeets froze, killing all of the seedlings and leaving us without a sugarbeet field to sample. All of the data from the corn fields in both 1998 and 1999 was included. Sediment (TSS) data from the dry bean field used in 1998 revealed that the producer was not applying PAM in the manner specified, resulting in considerably less soil and chemical losses from the untreated side of the field. PAM has been shown to reduce irrigation induced erosion from furrow irrigated fields by as much as 94 percent[4]. The untreated side of the dry bean field eroded less than 28% more than the treated side. This data combined with reports of frequent clogging of the PAM auger used to meter PAM into the irrigation water from the field technician made the 1998 data from the dry bean field highly suspect. In 1999, the producer growing dry beans did not increase the irrigation flow rates as needed to compensate for the slower advance of water treated with PAM. As a result, runoff from the PAM treated side of the field was insufficient to collect and analyze. In summary, the results presented here are from the 1998 and 1999 corn fields and all but the first irrigation on the 1998 sugarbeet field. The data for the first irrigation for these fields were averaged in order to track the difference between PAM treated and untreated irrigations. Each irrigation was analyzed separately in this way to track the effectiveness of PAM throughout the growing season. All of the data presented below is the difference between the treated and untreated acres; that is, how much of each constituent remained on the acres treated with PAM compared to the acres that were not treated.

PAM application: Producers were instructed to apply PAM at a rate of 0.6 ounces granulated anionic PAM per cubic foot of water (10ppm or one pound per acre) to one half of their fields during the furrow advance phase. PAM was to be applied to the first irrigation of the season and any irrigation following field cultivation not to exceed every other irrigation. Producers applied PAM at the recommended rate (excepting the dry bean field in 1998) but exceeded the recommended frequency in 1998 (see FIGURE 1). The general trend was to apply PAM with every other irrigation with decreasing frequency as the irrigation season progressed. The total amount of PAM applied averaged out to 5.23 kg/ha, which would be 1.87 kg/ha more than what was recommended to the producers. PAM effectiveness does not improve when applied more than every other irrigation[5], so any PAM applied more frequently would not be effective in further reducing sediment loss from treated acres.

Total Suspended Solids (TSS): Sediment savings were expected to be highest for the first irrigation of the season with secondary peaks whenever water was applied after a soil disturbing activity. Sediment losses were highest for the first irrigation with the second irrigation being almost as high (see FIGURE 2). However, nearly as much sediment was lost during the sixth and seventh irrigations. One possible explanation would be that some soil disturbing activity occurred between irrigations five and six that was not recorded by the producer. Total sediment savings for an irrigation season averaged 6822.81 kg/ha.

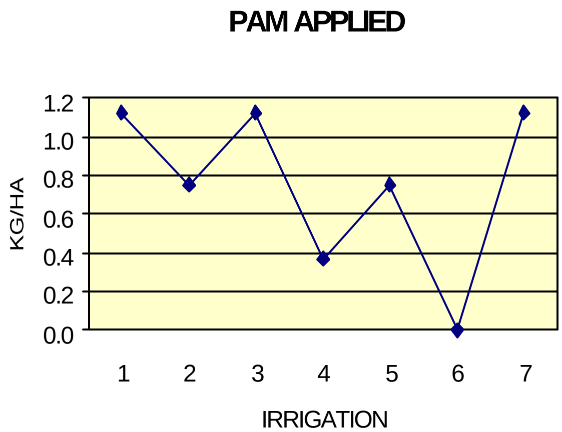

FIGURE 2

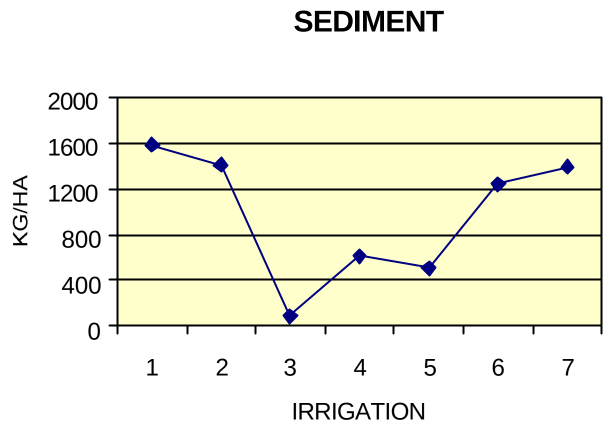

FIGURE 3

Ammonia (NH_3): Ammonia losses occur mostly through volatilization, not through deep percolation or runoff. Ammonia savings were highest for the first irrigation of the season (see FIGURE 4), but were comparatively negligible at 0.06 kg/ha. These savings were almost entirely offset by losses in the second irrigation from the treated acres, probably from deep percolation since ammonia moves with soil water and PAM improves infiltration[4]. Total ammonia savings for the irrigation season averaged only 0.01 kg/ha.

Nitrate-Nitrite (NO_3-NO_2): Nitrate-nitrite losses occur mostly from deep percolation. Nitrate and nitrite being negatively charged do not adsorb to clay particles and therefore move with soil water. Since PAM can improve infiltration rates by as much as 15%, it was expected that nitrate-nitrite losses would be higher on the treated acres. PAM did increase nitrate-nitrite loss as expected (see FIGURE 5) except for the first irrigation which was offset entirely by losses in the second irrigation. The irrigations when the most nitrate-nitrite was lost on the treated side roughly correspond to irrigations when the most PAM was applied. Total nitrate-nitrite losses for the irrigation season averaged 3.33 kg/ha.

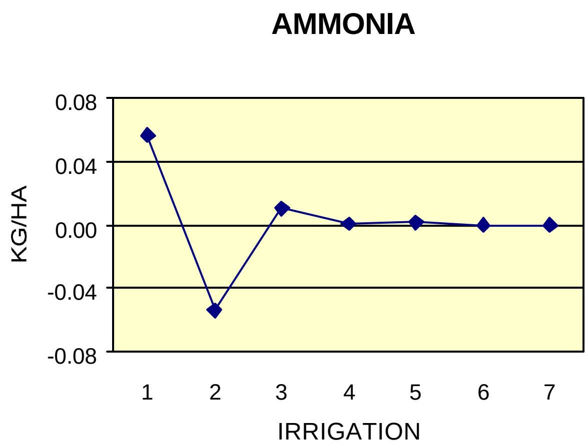

FIGURE 4

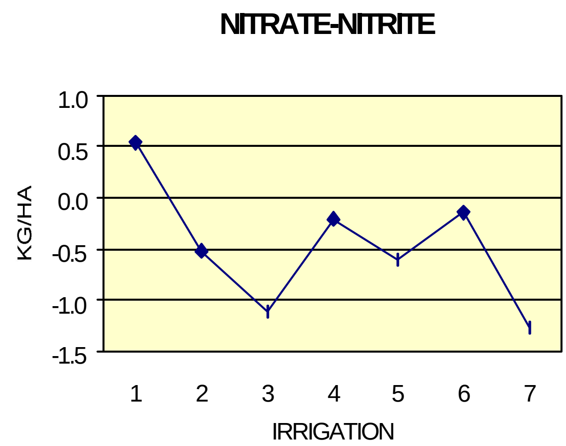

FIGURE 5

Total Kjeldahl Nitrogen: Total nitrogen includes ammonia, ammonium and organic nitrogen. Ammonium (NH_4) is positively charged and adsorbs to clay particles, and will therefore move with soil sediment during irrigation. Although organic nitrogen is not soluble in water, it will also move with soil particles during irrigation events. Therefore, it was expected that total nitrogen saved by PAM would be highest the first irrigation of the season when the most erosion occurs. Instead, the third irrigation was highest (see FIGURE 6). Manure applied in the fall and tilled into the soil and banded fertilizers applied in the spring may have been exposed by erosion that occurred during the first and second irrigations. Once these fertilizer materials were exposed, irrigation water carrying sediment would also carry ammonium and organic nitrogen off the field. Total nitrogen savings for the irrigation season averaged 4.91 kg/ha.

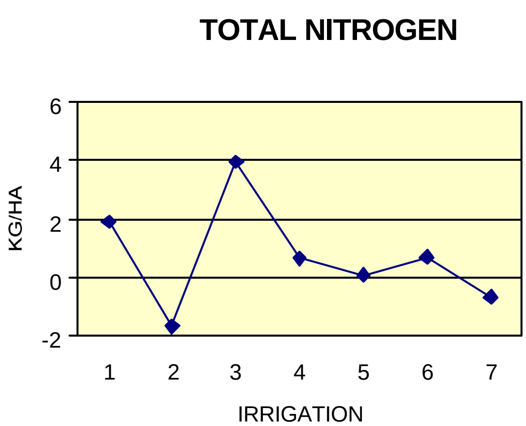

FIGURE 6

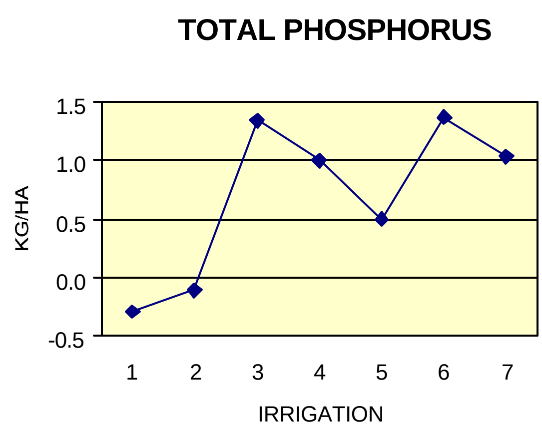

FIGURE 7

Total Phosphorus: Phosphorus is almost completely immobile in soil water, depending on soil pH. Therefore, it was expected that total phosphorus saved by PAM would be highest the first irrigation of the season when the most erosion occurs. Instead, the most phosphorus was saved during the third and sixth irrigations (see FIGURE 7). It is likely that what created a peak in total nitrogen during the third irrigation also happened to total phosphorus. The peak in the sixth irrigation could be explained by an unreported soil disturbance, as may have happened to sediment savings in the sixth irrigation. Total phosphorus savings for the irrigation season averaged 4.84 kg/ha.

Pesticides: Whenever a pesticide was applied, the irrigation following application was tested for that pesticide. These pesticides include Atrazine, Banvel (dicamba), Counter (terbufos), Dual (metalachlor), Lasso (alachlor), Lorsban (chlorpyrifos), and Poast (sethoxydim). Counter was banded in the sugarbeet field in 1998 prior to the first irrigation to control sugarbeet root maggots. All data for this irrigation was lost when the sample holding time was exceeded. Poast was sprayed on the dry bean field in 1998 to control grassy weeds. Data for the dry bean field is suspect for reasons previously stated. In addition, the EPA was unable to develop a standard for this pesticide before the sample holding time was exceeded. A tank mix of Atrazine, Dual, and Banvel was sprayed the corn field in 1999 before corn emergence to control weeds. None of the samples taken indicated these pesticides were leaving the field in runoff. Banvel is very mobile in water[6] and might not be detected in runoff. Dual is nearly immobile and both Atrazine and Dual have at least moderate persistence[6] and should have been detected. It is likely that when these chemicals were applied, the weed cover was too thick to allow contact with the soil in amounts significant enough to appear in runoff samples. In 1999, Lasso was sprayed and incorporated into the top three centimeters of soil prior to planting dry beans. Water samples revealed that Lasso was running off both the treated and untreated acres in nearly equal amounts with 0.01 kg/ha more Lasso running off the untreated side. The only pesticide that showed any significant savings with PAM was Lorsban. In 1998, Lorsban was banded at planting on the sugarbeet field for sugarbeet root maggot control. PAM treated acres lost 0.36 kg/ha Lorsban in the first irrigation.

Analysis: Data produced by the project was used to encourage adoption of PAM by local producers at several field days. More producers would be willing to implement this practice if a dollar value is put to the amount of chemicals saved when PAM is applied. These values were obtained by contacting local chemical dealers in November of 2000 to find the cost of the most common form of the chemical applied (see FIGURE 8).

Chemical	Amount Saved with PAM	Common Form	Cost	$/ha Saved with PAM
Sediment	6822.82 kg/ha	Topsoil	$21.45/tonne	$146.35
Nitrogen	1.60 kg/ha	Anhydrous ammonia 82-0-0	$3.52/tonne	$0.00
Phosphorus	4.84 kg/ha	Triple super phosphate 0-46-0	$330.00/tonne	$7.95
Chlorpyrifos	0.36 kg/ha	Lorsban 15G	$4.40/kg	$1.58
Alachlor	0.01 kg/ha	Lasso	$14.85/kg	$0.15
Total in runoff				**$156.03**
	Recommended Amount*			
Polyacrylamide	3.36 kg/ha	PAM	$11.00/kg	**$36.96**
Seasonal savings				**$119.07**

*Using PAM with every other irrigation for the season

FIGURE 8

Conclusion

Is PAM cost effective? The answer to the question of whether the cost of applying PAM is offset by the retention of agricultural chemicals depends on whether topsoil is considered in the equation. Most producers will not purchase topsoil to spread at the top of their fields after erosion has moved it to the bottom of the run. However, most producers will experience yield reduction from a loss of topsoil for a variety of reasons including reduced tilth, fertility and irrigation efficiency. Eroded sediment collects in tailwater ditches that need to be cleaned by moving the soil back to the top of the field. After many years of erosion the irrigation efficiency of furrow irrigated fields can change resulting in inadequate water distribution and poor yields. Some producers can pay as much as $3.00 per cubic meter leveling these fields to restore irrigation efficiency. Much of the topsoil remains lost, having moved off the farm altogether. Given these costs that producers already pay to maintain production, $146.35/ha could be a reasonable figure to reflect topsoil loss. Phosphorus is the second major contributor and is a direct cost to any producer adding phosphorus fertilizer to their fields. Pesticide losses contribute relatively little to the equation and these losses entirely depend on whether and how these pesticides are applied in the first place. It should be pointed out that soils more susceptible to erosion than those chosen for this project should lose more topsoil and agricultural chemicals in untreated runoff, provided that these chemicals were present in the same amounts. However, there are other considerations than the strict dollar value of the chemicals and topsoil lost to erosion. These include:

Pollution: Sediment and chemicals leaving crop fields can contaminate lakes and streams. Eroded sediments can clog the gills of fish and reduce the amount of light available to aquatic plants. Phosphorus provides source of fertilizer for algae in contaminated water bodies contributing to eutrophication. The effects of pesticides in contaminated runoff will depend on that pesticide but can include fish and invertebrate toxicity, concentration of pesticide in carnivorous species, and the death of aquatic plants. The cost of cleaning contaminated water bodies and restoring them to health and the cost of reduced recreation activities (fishing, boating, etc.) should also be considered.

New Pesticide Development: It is interesting to note that the one pesticide tested that PAM effectively prevented from moving off the field was Lorsban. Lorsban has recently come under scrutiny by the EPA, which has begun to restrict or eliminate some of the previously permitted uses for that pesticide. As a pesticide is eliminated from crop production, chemical companies spend millions of dollars to develop new pesticides to replace it. New pesticides tend to be much more expensive than pesticides that have been in use for some time to offset the cost of development. The potential cost of new chemical development should also be considered.

Pesticide resistance: Any pesticide that runs off the field will not be available to control the target pest. Pest populations exposed to a lesser concentration of pesticide will be more likely to develop resistance to that chemical. Eventually, the pesticide will no longer be effective in controlling pests and new chemicals will have to be developed. This cost of development (see above) and the crop yield loss from poor pest control should also be considered.

When is the best time to apply PAM? This depends on what type of pollution the producer wants to prevent. PAM should be applied in the first irrigation of the season and after soil disturbance to control soil erosion. Prevention of nutrient runoff will be determined by fertilizer type and application method. Banded fertilizers were exposed at the third irrigation and application of PAM was beneficial in retaining these chemicals on the field. Preventing pesticide runoff will depend heavily on the type of pesticide applied. Mobile, non-persistent pesticides will likely not be affected. Pesticides applied to bare soil instead of to weed or crop canopies are more likely to be kept on the field with PAM application.

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